Solenoid

200 mT Central Field · 40 mm Bore · Air- or Water-Cooled Configurations · Bipolar ±200 mT Sweep Capable

CUSTOM BUILD · Compact bore geometry · Triple-pancake water-cooled option · Continuous 200 mT operation · Field homogeneity ~0.1% over 4.5 mm

Compact-Bore High-Field Solenoid for Compact Magnetometry

Woodruff Engineering's Compact Solenoid delivers a 200 mT central magnetic field within a compact 40 mm bore for biomedical magnetometry, sensor characterization, and magneto-optical research applications requiring high field strength in a constrained working volume. Constructed as a precision dry-wound copper solenoid (1,250 turns of AWG12 magnet wire over 24 radial layers) mounted between 170 mm × 170 mm aluminium support plates, the system generates a highly uniform field with ~0.1% homogeneity over a 4.5 mm central region. The standard build supports bipolar operation with a –200 mT to +200 mT field sweep over 2 minutes, suitable for hysteresis characterization, retinal imaging workflows, and calibration of magnetically responsive samples.

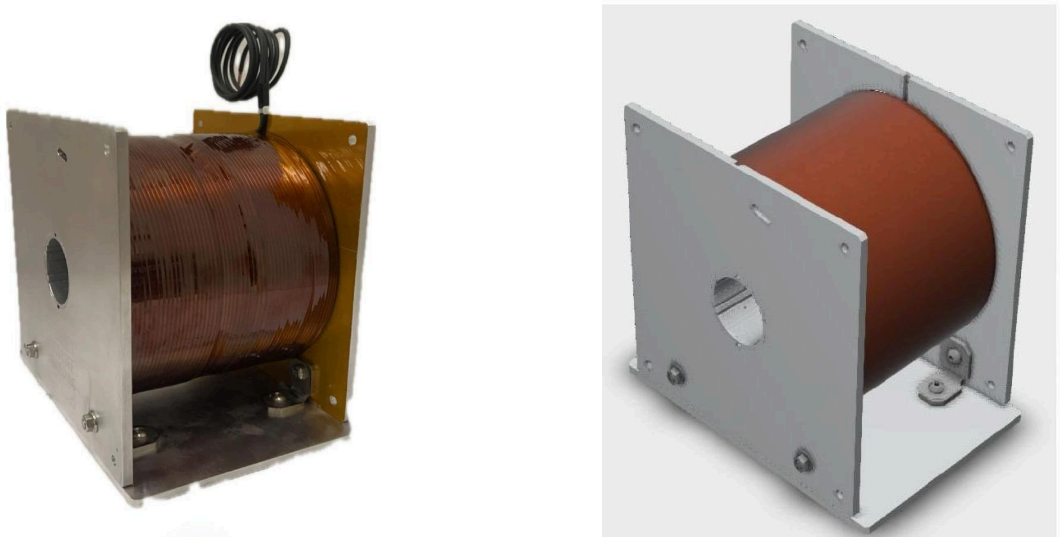

Figure: *Compact Solenoid — finished product. Left: completed assembly with coil-resistance verification. Right: CAD model*

Three Cooling Configurations to Match Duty Cycle

The Compact platform is offered in three thermal configurations to match the customer's duty cycle. The air-cooled baseline supports 200 mT pulses of approximately 5 minutes with moderate forced convection (cooldown to ambient in ~20 minutes), and 70 mT continuous operation. The water-cooled variant with two end-mounted cooling pancakes replicates this 5-minute pulse capability at 200 mT with significantly improved cooldown and repeat-pulse frequency. The triple-pancake variant with four water-cooling plates is the highest-performance option, enabling continuous 200 mT operation at 25 A / ~41 V / ~1 kW with a coil inner peak temperature of ~110 °C (assumes 20 °C inlet water), or 160 mT continuous at 20 A / ~33 V / ~660 W with a coil peak of ~70 °C.

Compact Mechanical Envelope and Mounting

The solenoid is supported between two 170 mm × 170 mm × 5 mm aluminium end plates with 120 mm separation, mounted on a 240 mm × 190 mm baseplate via four identical drilled support blocks (5 mm H12 fixings). The end plates provide a Ø37.5 mm clear bore for optical or sample access, with one face featuring a recessed sample-access feature. The 11 kg winding (354.6 m of AWG12 wire) is mechanically secured at each end plate. The complete assembly is engineered for benchtop integration with customer-supplied or

Woodruff-supplied DC power supply, and water-cooled variants include integrated cooling-plate manifolds compatible with a single 2 ft chiller unit.

PHYSICAL & MECHANICAL SPECIFICATIONS

External Diameter (winding)	150 mm *Outer diameter of completed winding (triple-pancake config)*
External Diameter (single-coil base)	141.75 mm *24 radial layers, 2.1 mm wire on Ø42 mm former*
Internal Diameter (bore)	37.5 mm *Clear working bore through solenoid*
Former Outer Diameter	40 mm *Aluminium / dielectric former OD*
Winding Length (axial)	120 mm *Active winding length along solenoid axis*
End Plate Dimensions	170 mm × 170 mm × 5 mm *Two aluminium support plates*
End Plate Separation	120 mm *Outer face to outer face along solenoid axis*
End Plate Mounting Holes	Ø5 H12, 10 mm from edge *Four corner holes per plate*
Bore Access Feature	Recessed sample port on one face *Customer-defined viewing / probe aperture*
Baseplate Dimensions	240 mm × 190 mm × 5 mm *Aluminium mounting baseplate*
Support Block Count	4 identical drilled blocks *20 mm × 20 mm × 5 mm, Ø5 H12 hole*
Estimated Mass (winding only)	~11 kg *Copper conductor mass*
Estimated Mass (complete assembly)	~18–22 kg *Configuration-dependent (air vs. water-cooled)*

WINDING SPECIFICATIONS

Conductor Type	AWG12 copper magnet wire *Dry wound, polyimide-grade insulation*
Wire Diameter	2.1 mm *Bare conductor + enamel*
Total Wire Length	354.6 m

	Per coil; abs. min 350 m, max 420 m, recommend 385 m allowance
Wire Mass	~11 kg *Copper only*
Total Turns	1,250 turns (nominal) *Min 1,200 / Max 1,250 per winding spec*
Winding Pattern	24 radial layers × 51–52 axial turns *Even layer count to return wire to entry end plate*
Coilgen Margin Target	1,210 turns (15% margin) *Customer target: 1,250 turns for 200 mT achievement*
Winding Method	Dry wound (no resin impregnation, standard) *Resin / VPI optional — quote on request*

ELECTRICAL SPECIFICATIONS

Nominal Operating Current	20 A DC *Continuous, single-pancake air-cooled config*
Peak Operating Current	25 A DC *Triple-pancake water-cooled config, continuous*
Coil Resistance @ 22 °C	1.69 Ω *Cold resistance, single solenoid*
Coil Resistance @ 30 °C	1.75 Ω (~1.74 Ω) *Recommended operating measurement temperature*
Voltage Drop @ 20 A, 125 °C	49 V *Hot-coil worst-case driving voltage*
Inductance (estimated)	Application dependent *Provided in as-built test report*
Sweep Capability	–200 mT to +200 mT in 2 min *Requires bipolar PSU; consult sales for matched supply*

MAGNETIC FIELD PERFORMANCE

Central Field @ 20 A (single, dry wound)	207 mT (216 mT projected @ 20 A peak) *1,250 turns, simulation-validated*
Central Field — Air-Cooled Continuous	70 mT *5 h continuous, free / forced convection*
Central Field — Air-Cooled Pulsed	150 mT (200 mT for ≤5 min) *10-min pulsed duty, forced convection*

Central Field — Water-Cooled Continuous (2 pancakes)	70 mT *5 h continuous*
Central Field — Water-Cooled Pulsed (2 pancakes)	150 mT (200 mT for ≤5 min) *10-min pulsed duty*
Central Field — Triple-Pancake (4 plates) Continuous	160 mT @ 20 A / 660 W; 200 mT @ 25 A / 1 kW *Highest-performance option*
Field Homogeneity at Center	~0.1% *Over 4.5 mm spherical region at coil center*
Field Polarity	Bipolar (sweep capable) *With appropriate bipolar power supply*

THERMAL & COOLING SPECIFICATIONS

Ambient Operating Temperature	15 – 30 °C *Standard laboratory environment*
Peak Coil Temperature (air, 200 mT, 5 min pulse)	~50 – 55 °C *Forced convection assumption (100 W/m²·K)*
Peak Coil Temperature (triple-pancake, 660 W)	~70 °C *Inner coil peak, 20 °C water inlet, continuous*
Peak Coil Temperature (triple-pancake, 1 kW)	~110 °C *Inner coil peak, 20 °C water inlet, continuous*
Cooldown Time (forced air, post 5-min pulse)	~20 min to within 10 °C of ambient *Moderate forced convection*
Cooldown Time (free convection)	Hours *Not recommended for repeated high-field pulsing*
Cooling Pancake Configuration A	2 end-mounted plates *5-min 200 mT pulse capable, faster recovery than air*
Cooling Pancake Configuration B	1 central plate (WE alternate) *Equivalent cooling; small effect on field uniformity*
Cooling Pancake Configuration C	3 pancakes + 4 cooling plates (high-perf.) *Continuous 200 mT operation*
Coolant	Water, 20 °C inlet (assumed) *Compatible with single 2 ft chiller unit*

POWER SUPPLY & ANCILLARY REQUIREMENTS

PSU Voltage Required	≥ 50 V DC (single config) *Allow margin for hot-coil resistance*

PSU Current Required	20 – 25 A DC *Configuration dependent*
PSU Type — Standard	Unipolar regulated DC *Customer-supplied or WE-supplied*
PSU Type — Sweep operation	Bipolar ±25 A regulated *Required for ±200 mT sweep*
Current Stability Recommended	< 0.1 % *For 0.1% field homogeneity to be exploitable*
Optional Chiller	Compact 2 ft benchtop chiller *Water-cooled configurations only*

AVAILABLE CONFIGURATIONS & PRICE INDICATION

Air-Cooled, 5-min 200 mT pulsed operation	~ $ASK *Baseline; suits intermittent high-field use*
Water-Cooled, 2 cooling pancakes + 1 chiller, 5-min 200 mT	$ASK *Improved pulse recovery vs. air-cooled*
Water-Cooled, 4 cooling pancakes + 1 chiller, continuous 200 mT	~ $ASK *Highest-performance / continuous-duty option*

Prices are indicative and subject to current quote; see Quote #1028 for water-cooled 2-pancake configuration. Lead times typically 8–12 weeks depending on configuration. Chiller, power supply, and field mapping services quoted separately on request.

DOCUMENTATION & DELIVERABLES

As-built data sheet	Included *Measured resistance, turns, dimensions*
Hipot / insulation test report	Included *Standard production QC*
B-field measurement at center	Included (single-point) *Gauss / Hall probe verification at delivery*
Field mapping service	Optional *Quote on request; mapped to customer-defined volume*
Operation & maintenance manual	Included *PDF + hardcopy*
CAD package	Optional *STEP/IGES on request, subject to NDA*

SIMULATION RESULTS

Magnetic Field at Target — Single Pancake, 1,250 Turns, 20 A

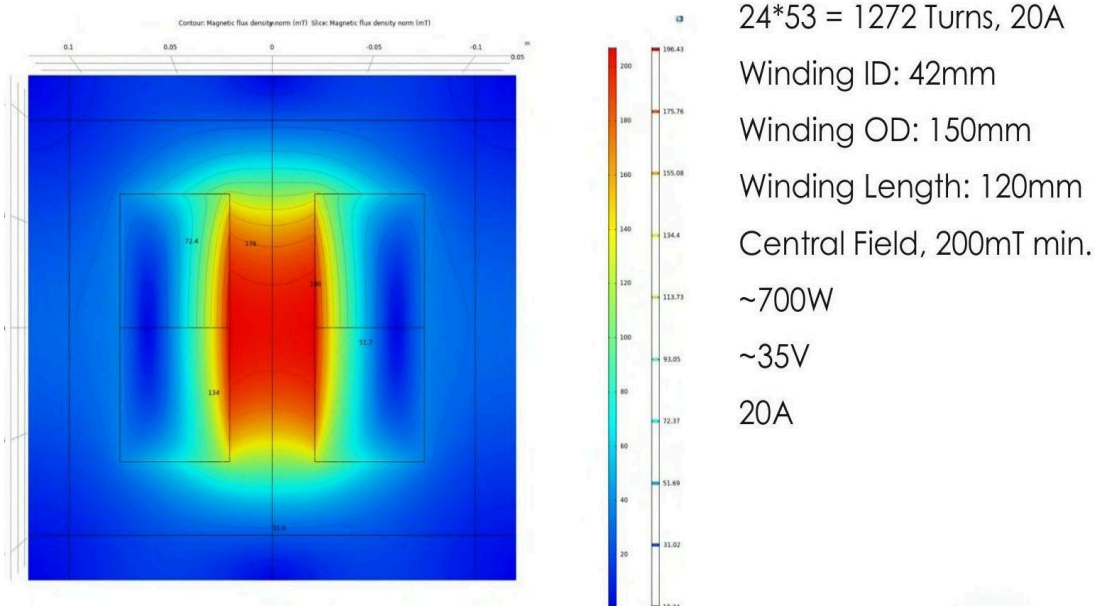

Figure: *COMSOL magnetic-flux-density simulation. Winding ID 42 mm, OD 150 mm, length 120 mm, 1,272 turns at 20 A. Central field ≥ 200 mT achieved at ~700 W / ~35 V terminal voltage.*

Cooldown After 5-Minute, 200 mT Pulse — Air-Cooled

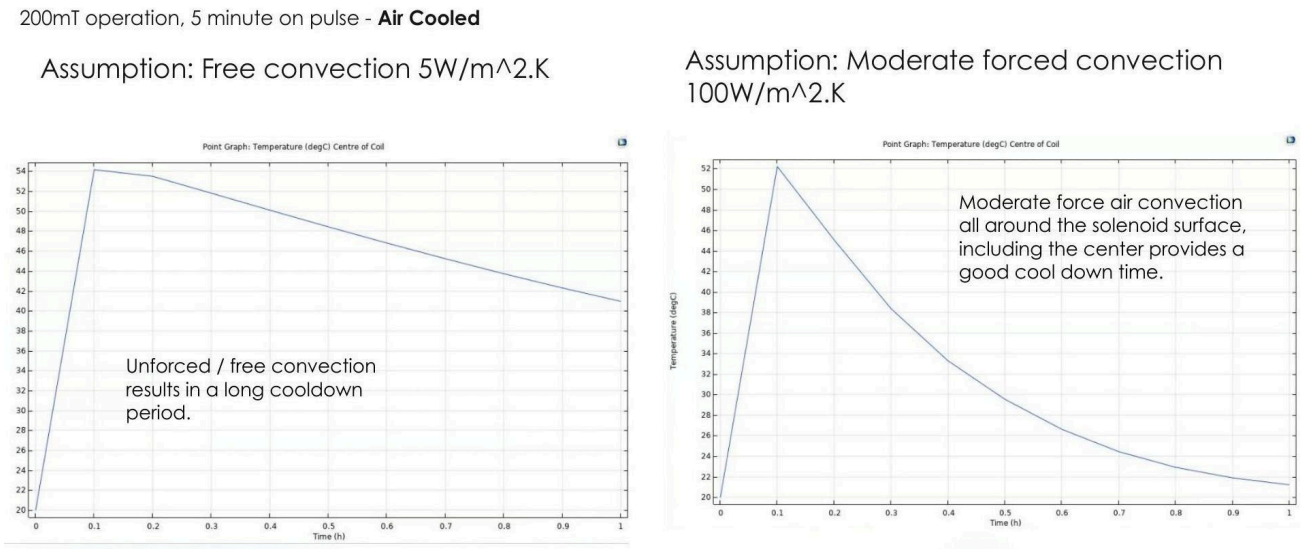

Figure: *Centre-of-coil temperature trace following a 5-minute 200 mT pulse. Left: free convection (5 W/m²·K) — long cooldown not recommended for repeated use. Right: moderate forced convection (100 W/m²·K) — recovery to near-ambient within ~30 minutes.*

Cooldown After 5-Minute, 200 mT Pulse — Water-Cooled

200mT operation, 5 minute on pulse - **Water Cooled**

Assumption: Crocus Design - Cooling pancakes (2) at ends.

Assumption: Woodruff Engineering Design - Cooling pancake (1) in middle

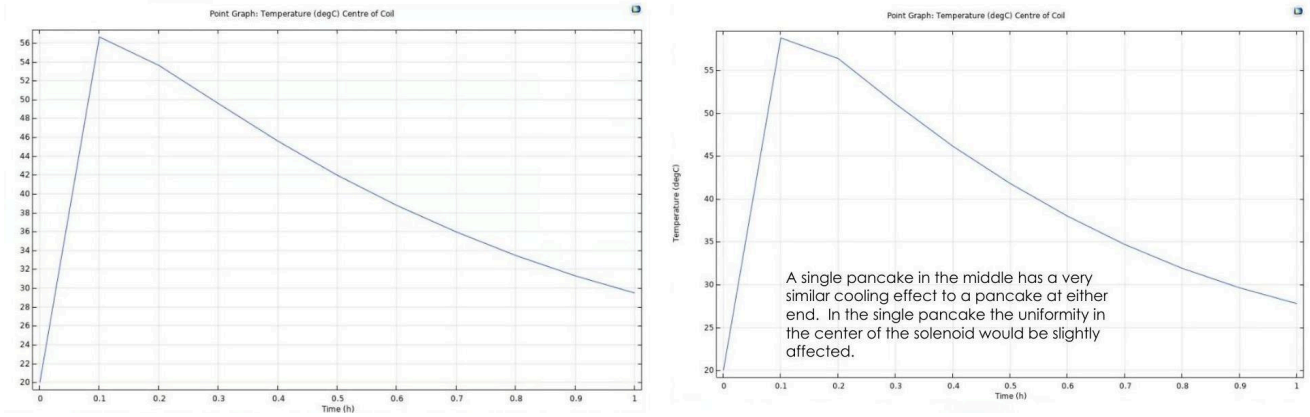

Figure: *Centre-of-coil temperature trace following a 5-minute 200 mT pulse with water cooling. Left: baseline — two end-mounted pancakes. Right: WE alternate — single central pancake. Bulk cooling effects are very similar; central uniformity is marginally affected by the single-central layout.*

Triple-Pancake Design — 660 W (160 mT Continuous)

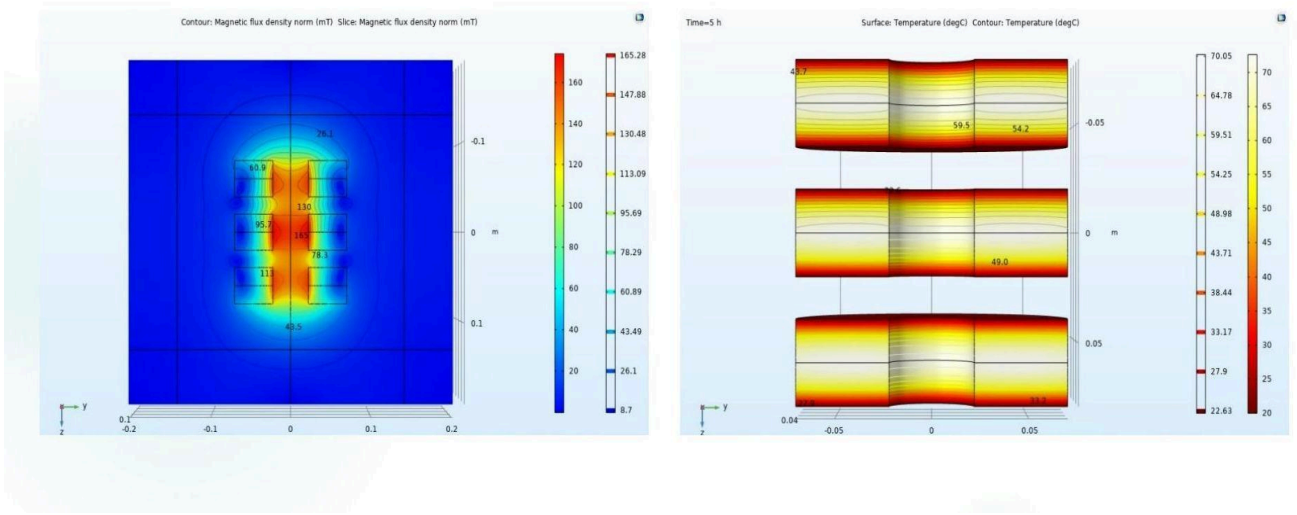

Figure: *3 pancakes, 4 cooling plates, 20 A / ~33 V / ~660 W. Left: magnetic-flux-density slice (peak ~165 mT at coil center). Right: steady-state thermal surface at 5 h, inner-coil peak ~70 °C with 20 °C water inlet.*

Triple-Pancake Design — 1 kW (200 mT Continuous, Highest Performance)

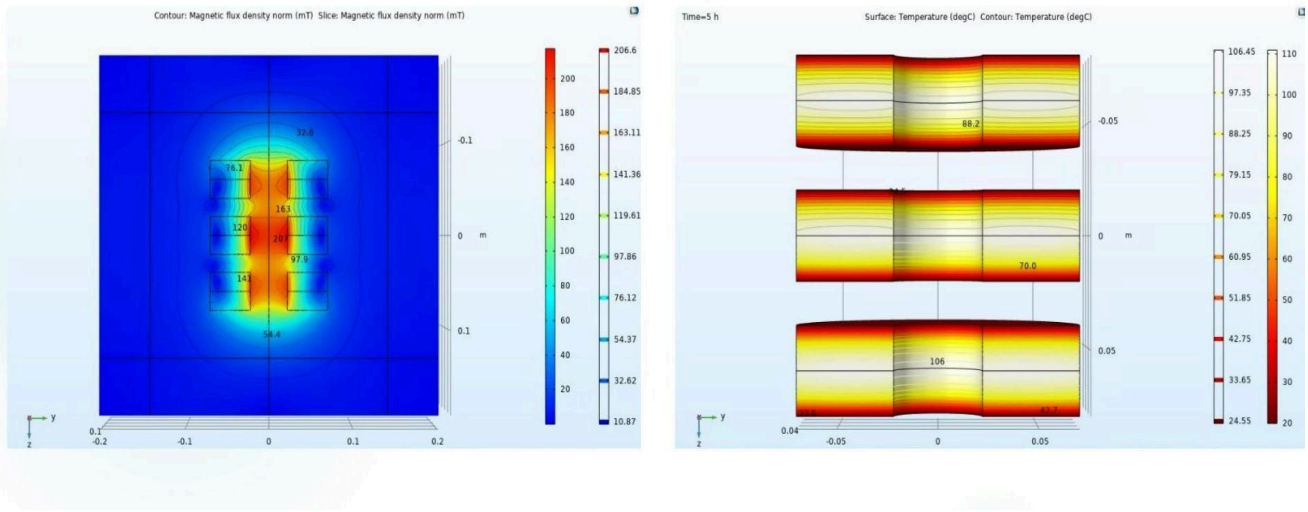

Figure: *3 pancakes, 4 cooling plates, 25 A / ~41 V / ~1 kW. Left: magnetic-flux-density slice (peak ~207 mT at coil center). Right: steady-state thermal surface at 5 h, inner-coil peak ~110 °C with 20 °C water inlet.*

On-Axis Field Profile — Triple-Pancake at 1 kW

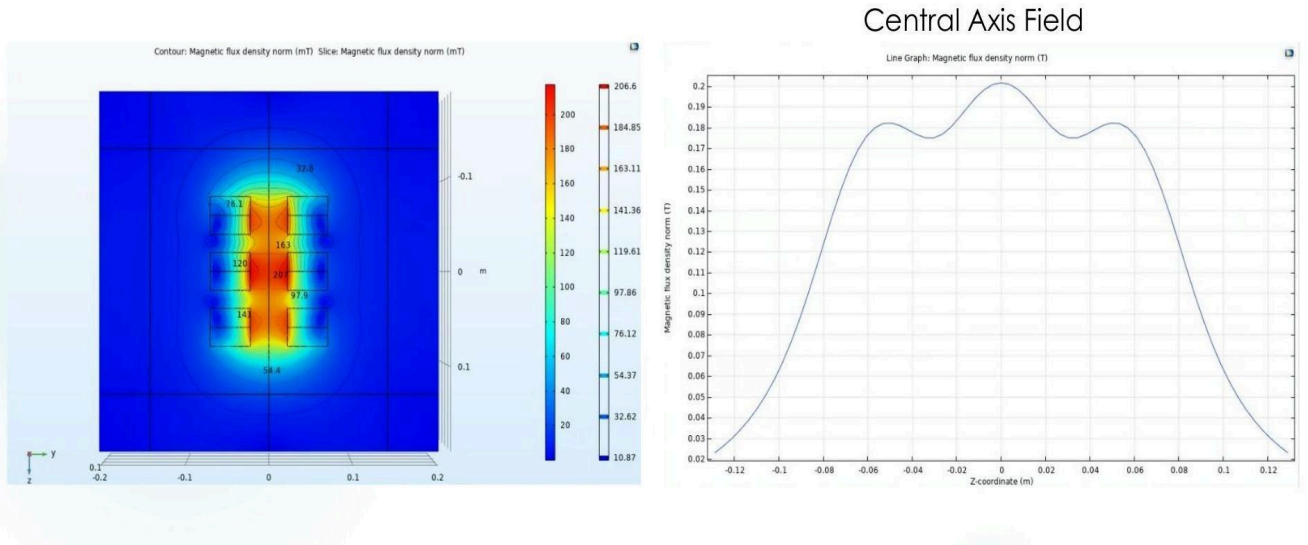

Figure: *On-axis field profile (Bz vs. z) for the triple-pancake design at 25 A. Three local maxima correspond to the three pancakes; central peak ≥ 200 mT over the ±20 mm working volume*

NOTES & OPERATING GUIDANCE

• Air-cooling combined with water-cooling delivers materially better performance than air-cooling alone — recommended for any user expecting multiple high-field pulses per hour.

• The single-central-pancake water-cooling variant produces very similar bulk cooling to the dual-end-pancake configuration; uniformity at the geometric center is marginally reduced and should be evaluated against the customer's working-volume requirement.

• For bipolar ±200 mT sweep operation, the customer is responsible for confirming PSU bipolar current capability and ramp rate (2-minute sweep from –200 to +200 mT corresponds to ~3.3 mT/s field slew, ~0.33 A/s current slew at the coil terminals).

Solenoid — Customer Order Form

Please complete the sections below. We will use this information to confirm scope, prepare a formal quotation, and define the as-built specification for your unit. Return this completed form to sales@woodruffeng.com. For complex customizations we may schedule a short technical consultation before quoting.

1. CUSTOMER INFORMATION

Organization / Institution	_____
Contact Name	_____
Email Address	_____
Phone Number	_____
Shipping Address	_____ *Include country and any import / customs notes*
End-Use Application	_____ *Brief description (e.g., retinal magnetometry, sensor cal, materials testing)*
Required Delivery Date	_____ *We confirm achievable lead time against current capacity*

2. COOLING CONFIGURATION (SELECT ONE)

- ☐ Air-Cooled (Baseline) — 5-min 200 mT pulsed operation; 70 mT continuous
- ☐ Water-Cooled, 2 Cooling Pancakes + 1 Chiller — 5-min 200 mT pulsed operation, improved recovery ·
- ☐ Water-Cooled, 4 Cooling Pancakes (Triple-Pancake) + 1 Chiller — continuous 200 mT operation ·
- ☐ Other / Custom — describe in Section 8 below

3. FIELD & OPERATING REQUIREMENTS

Required Central Field (mT)	_____ *Standard build: 200 mT. State alternative if different.*
Operating Mode	_____ *Continuous / Pulsed / Sweep (–B to +B) — circle one or describe*
Required Sweep Range (if applicable)	_____ *e.g., –200 mT to +200 mT*
Required Sweep Duration	_____ *Standard build: 2-minute sweep, –200 to +200 mT*
Pulse Duration (if pulsed)	_____

	Standard pulse: 5 minutes at 200 mT
Duty Cycle / Repetition	_____ *Pulses per hour; cooldown tolerance*
Field Homogeneity Spec	_____ *Standard: ~0.1% over 4.5 mm. State alternative if different.*
Working Volume	_____ *Diameter / dimensions of region where homogeneity must hold*

4. MECHANICAL CUSTOMIZATION

Bore configuration (select one):

- ☐ Standard Ø37.5 mm clear bore
- ☐ Custom bore diameter: _____ *mm (consult sales — may impact field and turn count)*

Sample-access port:

- ☐ Standard recessed port on one end plate
- ☐ Custom port location / geometry — describe in Section 8
- ☐ No port required (closed end plates)

Mounting orientation:

- ☐ Horizontal (standard — solenoid axis parallel to bench)
- ☐ Vertical (solenoid axis perpendicular to bench)
- ☐ Mountable on optical breadboard (M6 imperial pattern — confirm spacing)

Materials:

- ☐ Standard aluminium end plates and baseplate
- ☐ Non-magnetic stainless steel hardware throughout
- ☐ Vacuum-compatible construction (specify pressure regime in Section 8)

5. POWER SUPPLY

- ☐ Customer to provide PSU — coils only *(specify voltage / current capability below)*
- ☐ Woodruff Engineering to supply matched unipolar PSU
- ☐ Woodruff Engineering to supply matched bipolar PSU (required for sweep operation)
- ☐ Existing PSU integration support requested

Existing PSU Make / Model (if any)	_____
PSU Output Voltage Available	_____ *V*
PSU Output Current Available	_____ *A*
Required Current Ripple	_____ *% (typical: < 0.1% for full field homogeneity)*

Control Interface Required	_____ *Manual / Analog 0–10 V / RS232 / RS485 / Ethernet / LabVIEW / Other*

6. COOLING ANCILLARIES (WATER-COOLED CONFIGURATIONS ONLY)

- ☐ Include 2 ft benchtop chiller (standard, included in pricing above)
- ☐ Customer to provide chiller *(must supply ~20 °C water at adequate flow — consult sales)*
- ☐ Integrate with facility chilled-water loop *(specify supply temperature, pressure, and connection in Section 8)*

7. OPTIONAL DELIVERABLES & SERVICES

- ☐ Field mapping service (mapped to customer-defined volume)
- ☐ CAD package (STEP / IGES, under NDA)
- ☐ Extended factory acceptance test (FAT) with customer witness
- ☐ Operator training (specify number of personnel): _____
- ☐ Spare-parts kit (specify critical components)
- ☐ Extended warranty / service contract
- ☐ Annual recalibration service
- ☐ On-site commissioning support

8. ADDITIONAL REQUIREMENTS, CUSTOMIZATIONS, OR NOTES

_____

_____

_____

_____

_____

_____

9. CUSTOMER ACKNOWLEDGMENT

I confirm that the above selections accurately describe my requirements for the Compact Solenoid system. I understand that customizations may affect pricing, lead time, and the as-built specification.

Signature: _____	**Date:** _____
Printed Name: _____	**Purchase Order #:** _____

Submit completed form to: sales@woodruffeng.com · Quotation typically issued within 1 – 3 business days.

